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-: Name of the Research Topic: -

"Synthesis, Characterization of Mn and Zn doped CuO Thin films"

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Synthesis, Characterization of Mn and Zn doped CuO thin films

Introduction

The synthesis of nanoparticles (NPs) is presently an area of scientific research because they usually exhibit unique electronic, magnetic, optical and catalytic properties. Therefore, compared with traditional and commercial bulk material, they are very suitable candidates for biomedical, optical and electronic applications [1]. Metal oxide nanoparticles differ from bulk metals as they have low melting points, high specific surface area, good mechanical strength and improved optical and magnetic properties. Metal oxide thin films play a very important role in chemistry, physics and material science [2].

Transition metal oxides belong to a vital class of semiconductors, which have scientific and industrial applications in the field of magnetic storage media, solar energy conversion, electronics and catalysis [3]. In addition, metal oxides with multivalent oxidation states have attracted extensive attention from experts due to their wide range of interesting and exclusive properties such as nontoxic, eco-friendly and long term stability.

Recently, more attention has been paid to transition metal oxides thin films such as NiO, ZnO, TiO_2, Fe_2O_3 and CuO which have been used in the fields of magnetic storage media, resonance imaging, bio separation, medicine and wastewater treatment [4, 5]. Among various metal oxides, copper oxide (CuO) is one of the most popular p-type oxide semiconductors and gains considerable attentions due to its admirable optical, electrical, physical, and magnetic properties. CuO with narrow band gap of 1.2 eV is extensively used in various applications such as photovoltaic cell [6], electrochemical devices [7], gas sensors [8], solar cell [9], high efficiency thermal conducting materials [10], magnetic recording media [11], solar energy transformation [12].

The properties of pure CuO thin films such as structural, optical and electrical can be altered by doping with different transition metal. There are several reports are available in the literature in which they used transition metals such as nickel [13], cobalt [14], tin (Sn) [15], cadmium (cd) [16], Zinc (Zn) [17], Manganese (Mn) [18] etc. for the doping purpose.

Sonia et al. investigated that band gap of pure CuO nanoparticles is decrease from 3.01 eV to 2.49 eV with Zn doping [19]. Mohamed Basith et al. reported that the optical band gap of CuO films increased with Fe doping. Also Fe-doped CuO exhibited ferromagnetic behavior by doping of Fe to pure CuO [20].

R. O. Yathisha et al. study the I-V characterization pure and Zn doped CuO thin films. He observed that the photocurrent of pure CuO and Zn doped CuO films is greater in UV-light as compared to dark. Further they found that optical band gap of the pure CuO thin films decreases by the incorporation of Zn [21]. In this research work we will use Mn and Zn transition because of its comparable ionic radii. The ionic radius of Cu^{+2}, Mn^{+2} and Zn^{+2} is 0.73Å, 0.80Å and 0.74Å respectively [22].

Literature Survey

K.S. Khashan et al. fabricated CuO thin films on porous silicon substrate by spray pyrolysis method. To study structural, optical and electrical characterization, the fabricated films were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM), atomic force microscope (AFM) and UV-Vis spectrophotometer. From XRD study they found that all the films show polycrystalline and have monoclinic crystal structure. Optical study reveals that films have a low transmittance at the visible range and an optical band gap of 2.2 eV. Also they achieve high rectification with a maximum photoresponsitivity of about 0.59A/W at 400nm [23].

M. Shaban et al. investigated effect of influence of Cr-doping structural, optical and gas sensing properties of Cu_2O/CuO (mixed phase) thin film. The films were prepared by spin coating technique. Film crystallinity improves by increasing thickness and decreases the defects level in the films. The film sensitivity towards CO_2 gas at different gas flow rate was studied and compared with those of similar systems [24].

C. Hemalatha et al. studied structural, morphological, optical and magnetic properties of pure and Mn doped CuO thin films prepared by spray pyrolysis method. XRD analysis revealed that there is formation of monoclinic structure and the average crystallite size was 18 to 28 nm. From XRD pattern it observed that Mn is successfully incorporated in CuO without changing its basic monoclinic structure. The enhanced transmittance of the synthesized nanoparticles from ultraviolet to the red region suggests that these particles could be employed as a host material for optoelectronic applications. The band gaps of all the nanoparticles are found to be around 2.6 eV. The ZFC magnetization displays a sharp peak at 20 K and the FC magnetization saturated below this peak temperature [25].

H. A. Hussin et al. studied structural and optical properties of nanostructured CuO thin films doped by Mn at varying doping (2% and 4%). The films are prepared by chemical spray pyrolysis (CSP) method. Structural properties studied through the XRD analysis and it shows that all the films have polycrystalline structure with (002) orientation. Optical characterization of the films has been studied by UV-vis spectrophotometer and result shows that the pure and Mn doped CuO film has bandgap in the range of 1.72 to 1.92eV [26].

G. Durai et al. adopted a reactive magnetron sputtering method for the preparation of Mn doped CuO thin films. They investigated the microstructure and electrochemical performance of the Mn doped CuO thin films. The formation of monoclinic phase of CuO was confirmed by XRD analysis. The average crystallite size was found to be 19 and 15.5nm for pure and Mn doped CuO films respectively. The electrochemical measurements using cyclic voltammetry (CV) and galvanostatic charging with potential limited (GCPL) method were used to the measurement of electrochemical super capacitive performance of the Mn doped CuO film electrodes. It is observed that capacitance of the Mn doped CuO thin film enhanced with the doping concentration. Also the Mn doped CuO films showed a maximum columbic efficiency of about 96%. This result shows improved electrochemical performance of the cost effective Mn substituted CuO films for the next generation energy storage applications [27].

H. Zhu et al. fabricated highly (111) oriented Mn doped CuO thin films on silicon substrate by radio frequency magnetron sputtering method. An X-ray photoelectronic spectroscopy (XPS) and resistivity study indicates that Cu and Mn ions have 2^+ valences in the thin films. Also they observed ferromagnetism for the 15.2% - 29.8% Mn doped CuO thin films with transition temperature 87 and 99.5 K [28].

M. Nesa et al. reported the structural, optical and electronic properties of CuO and Zn doped CuO have been studied using DFT based First-principles calculations. From the electronic structure they computed electronic band structure, TDOS and PDOS of pure and Zn doped CuO films. From the analysis of electronic structure, the pure CuO material shows semiconductor nature with small band gap and Zn doping CuO behaves like metallic semiconductor. Also they study frequency dependent optical parameters of the Pure and Zn doped CuO films [29].

S. Roy et al. studied the impact of substrate temperature on structural, optical and electrical properties of CuO thin films. They found that the optical transmittance of the film is decrease with increase in substrate temperature. Optical band gap varies from 1.90 eV to1.60 eV and the room temp electrical resistivity varies from 30 to 18 ohm-cm [30].

L. Muthaiyan et al. reported the electronic transport properties of pure and Zn doped CuO armchair nanotubes by using density functional theory. Zn doped CuO showed enhanced transport properties than the pure nanotubes due to the 'd' orbital overlapping. Similarly, the NH_3 adsorption on the Zn doped CuO has enhanced the current flow through the device [31].

Motivation

Compared with other transition metal oxides (such as ZnO, SnO_2, TiO_2, and Fe_2O_3), the synthesis and characterization of CuO thin films is the least explored area, which makes it an interesting candidate for studying its properties. In addition, doping semiconductor nanoparticles with impurity metal ions is one of the most important ways to modify the material properties.

Objective

1. To prepare thin films of copper oxide (CuO), Mn doped CuO and Zn doped CuO by chemical spray pyrolysis method.
2. To study the effect of Mn and Zn dopant on structural, morphological, optical and electrical properties of CuO thin films for its better applications in various fields.

Hypothesis of Research

The research work is directed to prepare Mn and Zn doped CuO thin films. In this work we proposed to have improved structural, optical and electrical properties of pure CuO thin films by doping of Mn and Zn.

Research Methodology

Thin Film Deposition

In recent years, extensive efforts have been made in the preparation, characterization, and application of metal oxides thin films. Thin film deposited by various techniques such as electrochemical deposition [32], Pulsed laser deposition [33], sol gel spin coating methods [34], and chemical spray pyrolysis [35]. In the present study, we propose to use spray pyrolysis method for preparing pure and doped CuO thin film.

Characterization

The prepared thin films will be characterized as follows:

- Structural properties by X-ray diffraction (XRD) measurement
- Surface morphology study by Scanning Electron Microscopy (SEM)
- Optical properties by UV-Vis Spectroscopy
- Electrical measurement by two probe /four probe method

Chapter Scheme

Chapter 1: Introduction.

Chapter 2: Experimental and characterization techniques.

Chapter 3: Synthesis and characterization of Mn **doped CuO** thin films.

Chapter 4: Synthesis and characterization of **Zn doped CuO** thin films.

Chapter 5: Conclusion and scope for future.

Proposed Work Plan

Year – wise plan of work and targets to achieve.

Year I – Plan:

In the first year we will do literature survey on Mn and Zn doped CuO thin films. The literature includes collection of Journals, Books and some research papers related to the research work will be completed. Further we will place order for the chemicals which will use for the preparation of thin films.

Year II – Plan:

In second year, efforts have been taken for the preparation of good quality CuO, Mn doped CuO and Zn doped CuO thin films by spray pyrolysis technique. The structural, morphological, optical and electrical properties of prepared film will be studied by using XRD, SEM, UV-VIS spectrophotometer and two probe/four probe measurement system.

Year III – Plan:

In the last year, we will prepare Research papers to send them for the publication in reputed journals at national and international level. Further we will submit the final thesis of the proposed work for doctoral degree.

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